GORDON EXTRA-TROPICAL DEPRESSION OVER PORTUGAL: A CASE STUDY WITH WRF (version 2.2).

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Abstract

The 2.2 version of the Weather Research and Forecasting (WRF) model has been used to investigate the atmospheric behavior on extreme weather events, such as the passage of the Gordon extra-tropical depression over the Iberian Peninsula, on September 21st, 2006. The study of this particular event has been conducted using two nested domains, with 15 and 3 km resolution, respectively, and its results are directly compared with observational data collected by several Automatic Meteorological Stations, from the Portuguese Meteorological Institute, for the time span of the event.

1. INTRODUCTION

The hurricane Gordon was one of the most intense events of the 2006 Atlantic Hurricane season, making it the first hurricane to directly impact the Azores since Bonnie, in 1992. Formed near Leeward Islands, Gordon was first declared as a tropical depression (at September 10th) moving northwestward, evolving later to a tropical storm (September 11th) and reaching category 3 on the Saffir-Simpson scale, on September 13th.

Since its formation, the hurricane was moving easterly and the initial forecasts pointed to a high intensity impact over the Azores islands, which lead to the activation of several security measures. However, the damage caused by Gordon was limited to toppled trees and power lines, knocking out power to some communities, particularly on Santa Maria Island.

After crossing the northwest region of the Iberian Peninsula, on September 21st, the event came to the end of its lifecycle, being absorbed by an Atlantic low pressure area, located over the west of the United Kingdom.

Having in mind the meteorological conditions developed during this event, some studies can be made, in order to evaluate the performance and versatility of the Weather Research and Forecasting (WRF) model in such an anomalous behavior of weather systems.

2. DESCRIPTION OF WRF USE AND CONFIGURATION

The WRF model has been used in real time at the Physics Department of Aveiro University (UA) since 2001, providing forecasts of up to 120 hours. Its implementation (along with MM5) envisaged the constitution of a basic tool to conduct studies of mesoscale weather phenomena that affect the Portuguese continental area and its surroundings as well as the development of a web-based real time forecast system to the community. [1]

The 2.2 version was built on a 4 node Intel Pentium D based cluster, and the operational 120 hour runs use a nested domain of one 21 km grid, centered around 40 N latitude and 5.4 W longitude, and a 7 km grid covering the whole Portuguese territory. The model is initialized with the 00:00 UTC 3 hourly analysis and forecast data produced by the National Centers for Environmental Prediction (NCEP) Global Forecast (GFS) model (in GRIB1), received via Unidata Local Data Manager (LDM), at the Physics Department of UA.

For this particular study, the simulation period was reduced to 72 hours and a different domain configuration was used, as figure 1 depicts. Also, a similar run was performed with the European Center for Medium Range Weather Forecasting (ECMWF) model providing initial conditions and lateral boundary conditions to evaluate eventual differences between both types of initialization data.

FIGURE 1: Domain configuration for the present study.

The most relevant configuration parameters are:

- Nested 1:5 grid configuration, with the coarser 15 km grid spacing domain centered around 40.6 N latitude and 15.4 W longitude;
- 30" resolution geographical data on both nests;
- 40 vertical levels;
- 90 s integration timestep on the coarser nest, 18 s on the finer.

As for the physics parametrizations, they were kept similar to the operational runs, as shown in Table 1.

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[1] As it can be seen in `http://www2.fis.ua.pt/torre`.

Physics Options	Scheme
Microphysics	Eta microphysics
Longwave Radiation	RRTM
Shortwave Radiation	Dudhia
Surface Layer	MM5 similarity
Land Surface	5 layer thermal diffusion
PBL Layer	Yonsei University
Cumulus Parametrization	Kain-Fritsch

Table 1: Physics parametrizations of the WRF ARW model.

3. RESULTS

On a first, crude analysis, simulated data, based on GFS initialization resembles, very closely, the conditions observed, as figures 2 and 3 depicts, for the case of the mean sea level pressure field and the Meteosat 8 infrared image.

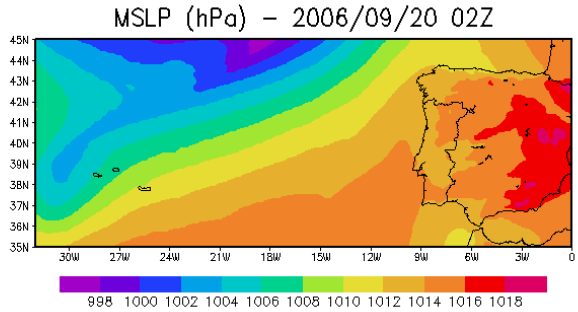

FIGURE 2: Mean sea level pressure, for 20th September, at 2:00, from the GFS-driven simulation.

FIGURE 3: Meteosat-8 channel 4 image (λ = 3.9μm) for 20th September at 2:00.

The 10 m wind magnitude field for 7:00, also from the GFS initialized run, shows some interesting characteristics, as it can be seen in figure 4.

4. DATA ANALYSIS/VALIDATION

In order to evaluate the quality of the simulated forecasts, the results were compared with observable surface

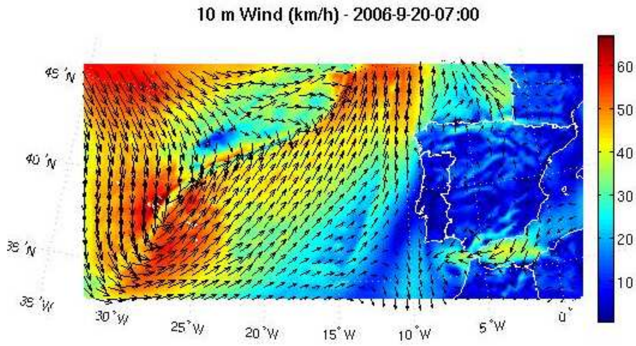

FIGURE 4: 10 m wind direction and magnitude for 20th September at 7:00 (localtime).

data collected by several Automatic Meteorological Stations (AMS), from the Portuguese Meteorological Institute network, for the the time period ranging from 5:00 to 9:00 (localtime) of the 21st September 2006.

Figures 5 and 6 show a slight concordance between simulated and observed mean sea level pressure. It should be noted, however, how the ECMWF initialized results seem to approach more accurately the observed data.

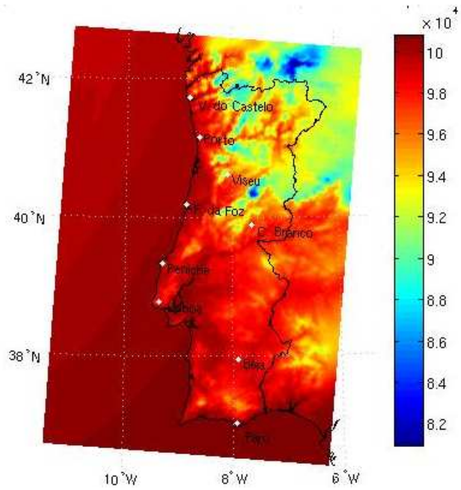

FIGURE 5: Mean sea level pressure (hPa) predicted by WRF, for 21/09/2006 at 5:00 (localtime).

As for the wind intensity, one can clearly acknowledge, from an analysis to figure 8 that, in spite of reproducing reasonably its local variability, the simulations clearly underestimate the wind magnitude. On the other hand, and having in mind the comparison between both types of initialization data, figure 8 also shows that, although the ECMWF initialized run produces higher 10 m wind magnitudes, its results are still very distant from the observational data.

On what concerns total hourly precipitation, figures

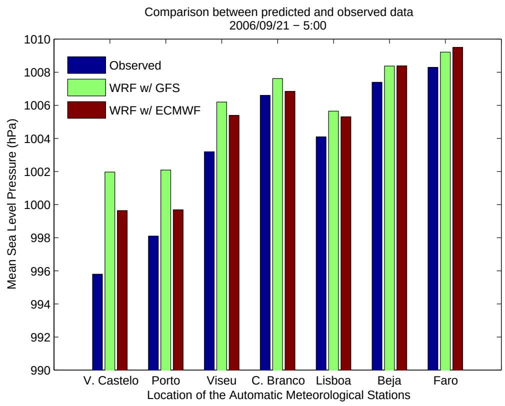

FIGURE 6: Comparison between observed and predicted mean sea level pressure (hPa).

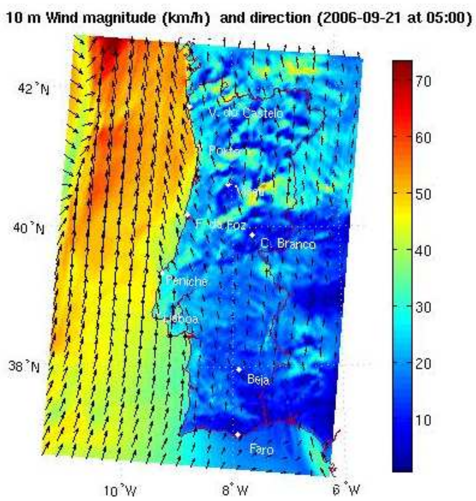

FIGURE 7: Simulated wind field for 2006/09/21 at 5:00 (localtime).

9 and 10 show respectively the total accumulated precipitation from 5:00 to 6:00 estimated by the GFS-driven run and the radar reflectivity image for 6:00.

From the above figures and comparing figures 11 to 13, it can, thus, be noticed a delay on the predicted hourly precipitation rate, from both types of initialization data as well as an underestimation of the total precipitation measured by the Automatic Meteorological Stations. Although the ECMWF driven simulation provides a larger amount of accumulated hourly precipitation for 8:00, the predicted values are still below the quantities measured, which make these results inadequate for a real-time forecast.

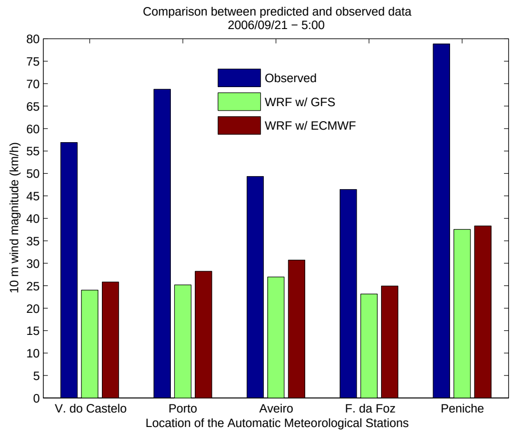

FIGURE 8: Comparison between observed and predicted 10 m wind magnitude (km/h).

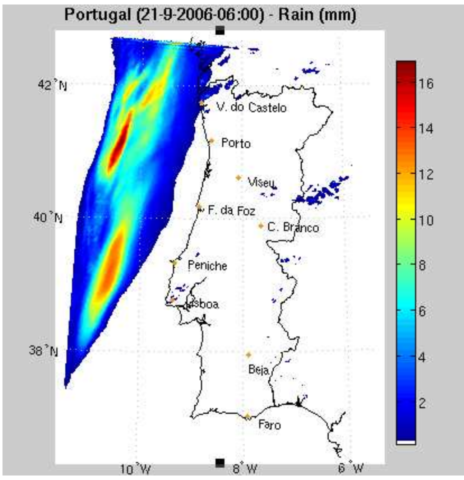

FIGURE 9: Simulated total precipitation for 6:00 (mm), from the GFS initialized simulation.

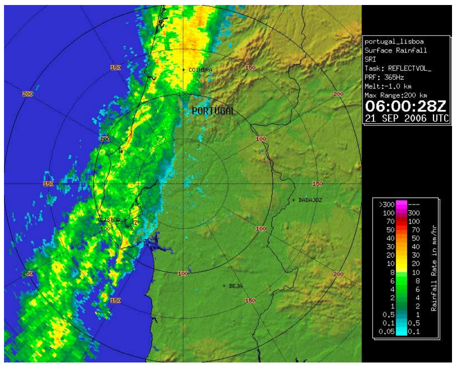

FIGURE 10: Radar reflectivity image for 6:00

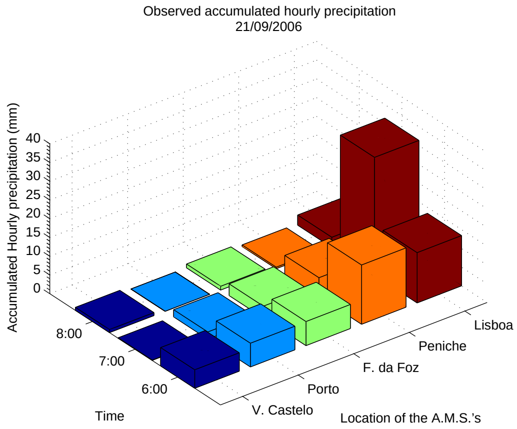

FIGURE 11: Distribution of the observed total accumulated hourly precipitation (mm).

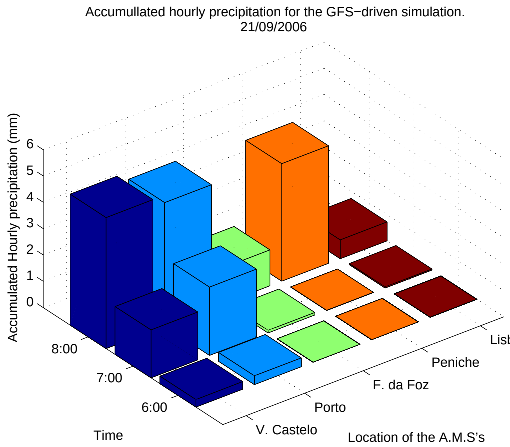

FIGURE 12: Distribution of the GFS-driven WRF run total accumulated hourly precipitation (mm).

5. CONCLUSIONS

Unfortunately, a successful WRF run, reproducing accurately all the conditions observed, could not be shown. Nevertheless, the lack of success should not be pointed out as a deficient model calibration/parametrization, but, instead, by the initial-boundary conditions used.

A solid conclusion that can be made lies on the fact that the ECMWF data used as initial-boundary conditions provides a slight improvement on the simulation results, in comparison with the GFS model data.

Further explorations of this unusual situation shall include data assimilation from the Portuguese Meteorological Institute Automatic Meteorological Stations, in order to minimize eventual errors from the initial and lateral

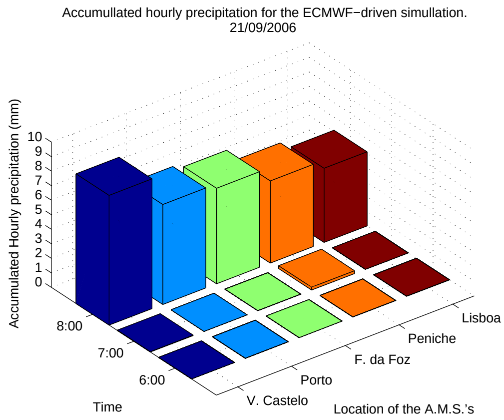

FIGURE 13: Distribution of the ECMWF-driven WRF run total accumulated hourly precipitation (mm).

boundary conditions data.

6. ACKNOWLEDGMENTS

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References

Mass, F. C., D. Ovens, K. Westrick, and B. A. Colle, (2002): Does increasing horizontal resolution produce more skillful forecast? *Bull. Amer. Meteor. Soc., 83, 407-430*;

REVIEW OF THE PAST HURRICANE SEASON - RSMC Miami 2006 Atlantic and Eastern North Pacific Hurricane Season Summary (2006), online in `http://www.wmo.ch/web/www/TCP/Meetings/HC29/EN/Doc4RSMCMiami.doc` (2007/05/10);

Skamarock, W. C., et al (2005): A Description of the Advanced Research WRF Version 2, online in `www.mmm.ucar.edu/wrf/users/docs/arw_v2.pdf`

User's Guide for Advanced Research WRF (ARW) Modeling System Version 2.2 (2007), online in `http://www.mmm.ucar.edu/wrf/users/docs/user_guide/` (2007/05/10)